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The Relationship Between Environmental Conditions and UH-60 Cockpit Temperature

By

Robert Thornton

and

Frank Guardiani
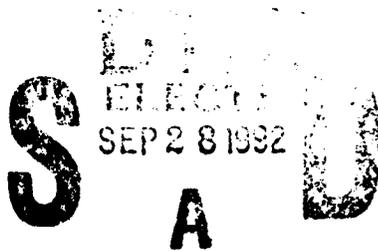
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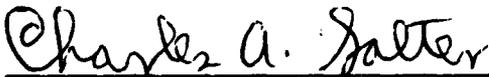
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Data have been collected in the UH-60 helicopter in various flight configurations (hover, contour (250 ft) and cruise (650 ft)) to relate the thermal conditions found in the cockpit to data available to commanders and researchers in the field. These have been used to develop equations for use in future thermal modelling studies, and to provide information to increase the fidelity of helicopter environmental simulations.

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Preface

This study was conducted under the auspices of the Department of the Army program, the Physiological and Psychological Effects of the NBC Environment and Sustained Operations on Systems in Combat (P^2NBC^2). The study was designed to meet the P^2NBC^2 goals and objectives, and was partly funded by the P^2NBC^2 program.

Acknowledgments

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Introduction

There is a considerable greenhouse effect in the cockpit of most helicopters, making conditions inside much hotter than outside. This is particularly so in direct sunshine, and if cockpit ventilation is reduced, for example, to prevent Nuclear, Biological, and Chemical (NBC) contamination.

Information on environmental climatic conditions is readily available, particularly to the aviation community, but there is no way at present to relate that to conditions which may pertain in aircraft cockpits. This makes it impossible to give accurate guidance on safe exposure times when flying in NBC equipment at high outside temperatures.

Thermal modelling of the physiological effects of wearing NBC equipment may eventually allow commanders to predict the likely degradation in performance caused by flying at particular NBC states in various climatic conditions. A prerequisite for that is more detailed knowledge of the internal cockpit environment. One of the main objectives of the study was to produce a database which would enable accurate prediction of cockpit conditions, given the outside weather, flight plan, time of day, and time of year.

Accurate simulation of helicopter cockpit conditions in the U.S. Army Aeromedical Research Laboratory UH-60 research flight simulator requires detailed information about the conditions pertaining in the aircraft.

Methods and materials

Heat stress index

Among the several available indices for heat stress measurement, the index of choice for this study was the Wet Bulb Globe Temperature (WBGT) index. The WBGT's most favorable characteristics are its easy application and the insignificance of wind speed measurements to its calculation (Minard, 1964). The WBGT is calculated from dry bulb (T_{db}), wet bulb (T_{wb}), and black globe temperatures (T_{bg}), using the following equation (Yaglou and Minard, 1957):

$$WBGT = 0.7T_{wb} + 0.2T_{bg} + 0.1T_{db}$$

Temperature measurement

The temperatures were recorded during flight in a UH-60 helicopter using Reuter-Stokes integrated WBGT sensors* (Figure 1). Each unit had warranted factory calibration to cover the period of its use in the study. It stores all three component temperatures and computes the WBGT. For the purposes of this study, they were set to record data at one minute intervals.

To record the environmental data, two sensors were mounted on tripods, 4 feet from the ground. One was placed on grass in front of the USAARL building, the other at High Falls stage field, where the hover portions of the flights were performed.
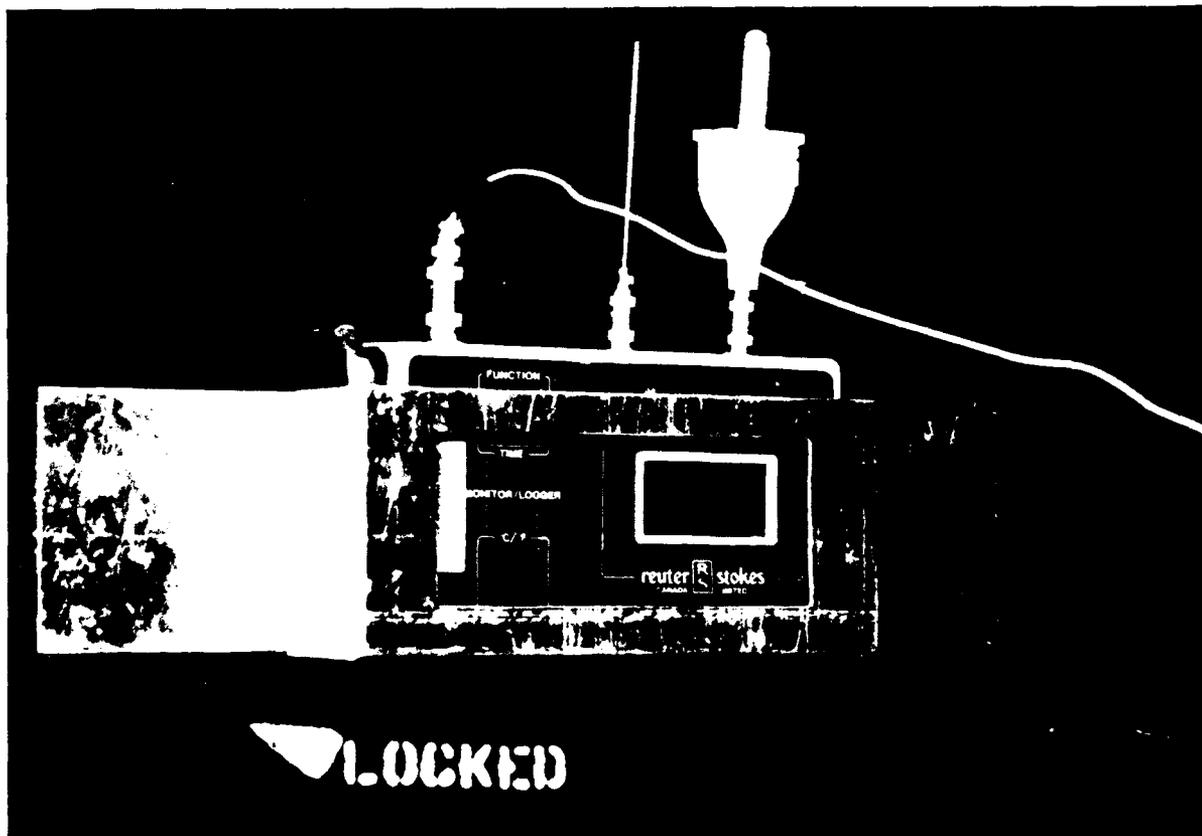
Figure 1. Reuter-Stokes Wibget.

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*See manufacturer's list, Appendix A

In the aircraft, two sensors were placed in the rear cabin, one on the stretcher litter, the other near the gunner's window. Neither normally received direct sunlight. In the cockpit, a configuration was designed so that the black globe temperature could be measured in direct sunlight, as near to the copilot's head as possible, while the dry and wet bulb sensors were shielded from direct radiation (Figure 2). A black globe was mounted on a bracket which could be readily attached to the co-pilots's overhead circuit breaker panel, using heavy duty hook and loop type fasteners. A thin gauge wire was threaded from it, behind the pilot's seat to the door. The recording unit was located in the door pocket, with its dry and wet bulb sensors attached (Figure 3).
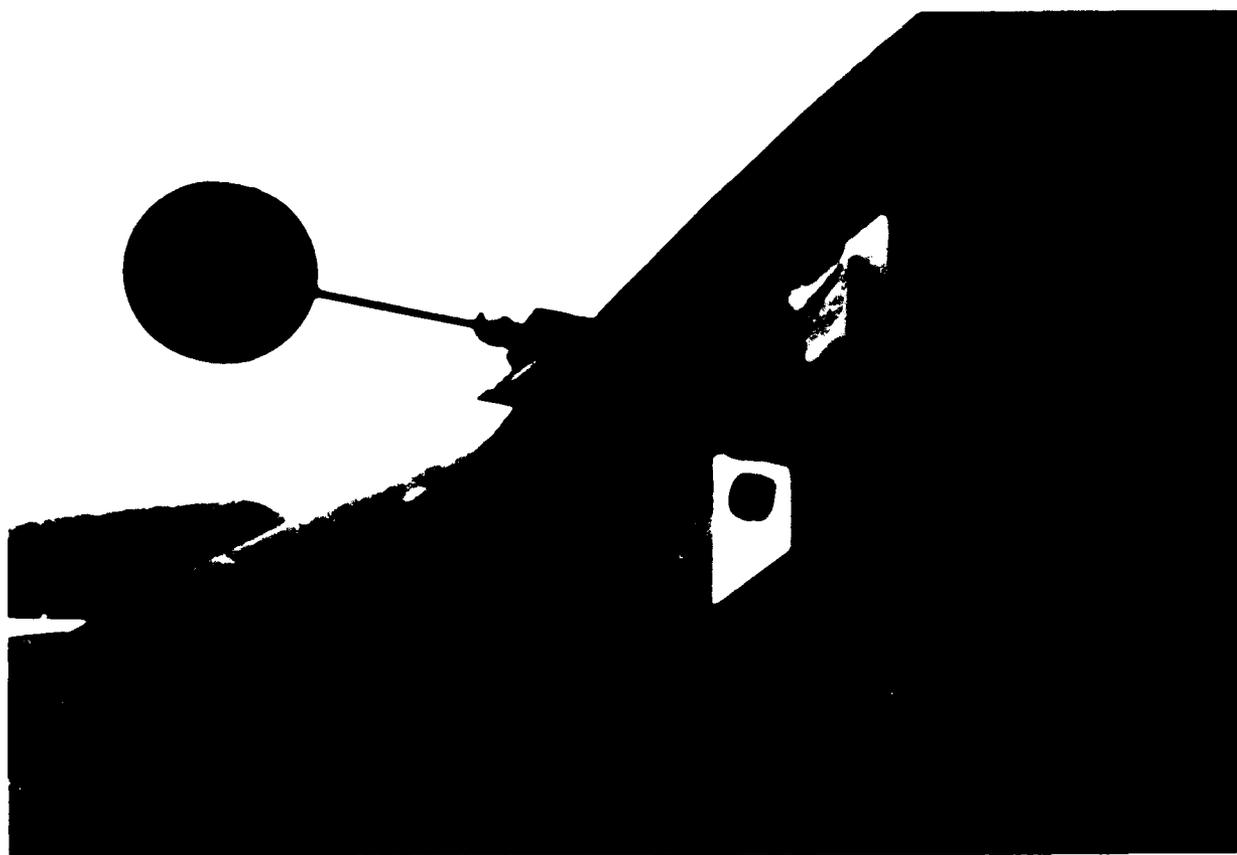
Figure 2. Roof-mounted Wibget.

Radiant heat load

Th. radiant heat received at the head of the pilot is an important component which was missing from the original design of the USAARL UH-60 research flight simulator. A Matrix Inc. pyranometer was used to measure this factor during the summer months. A pyranometer is a type of actinometer that measures the combined intensity of direct solar radiation and diffuse sky radiation received on a horizontal surface. The measured radiant flux density is given in units of watts per square meter (W/sq m). The original plan was to make regular recordings throughout the flight. Devising a safe mount which would not pose a significant hindrance to the pilot proved impossible, and
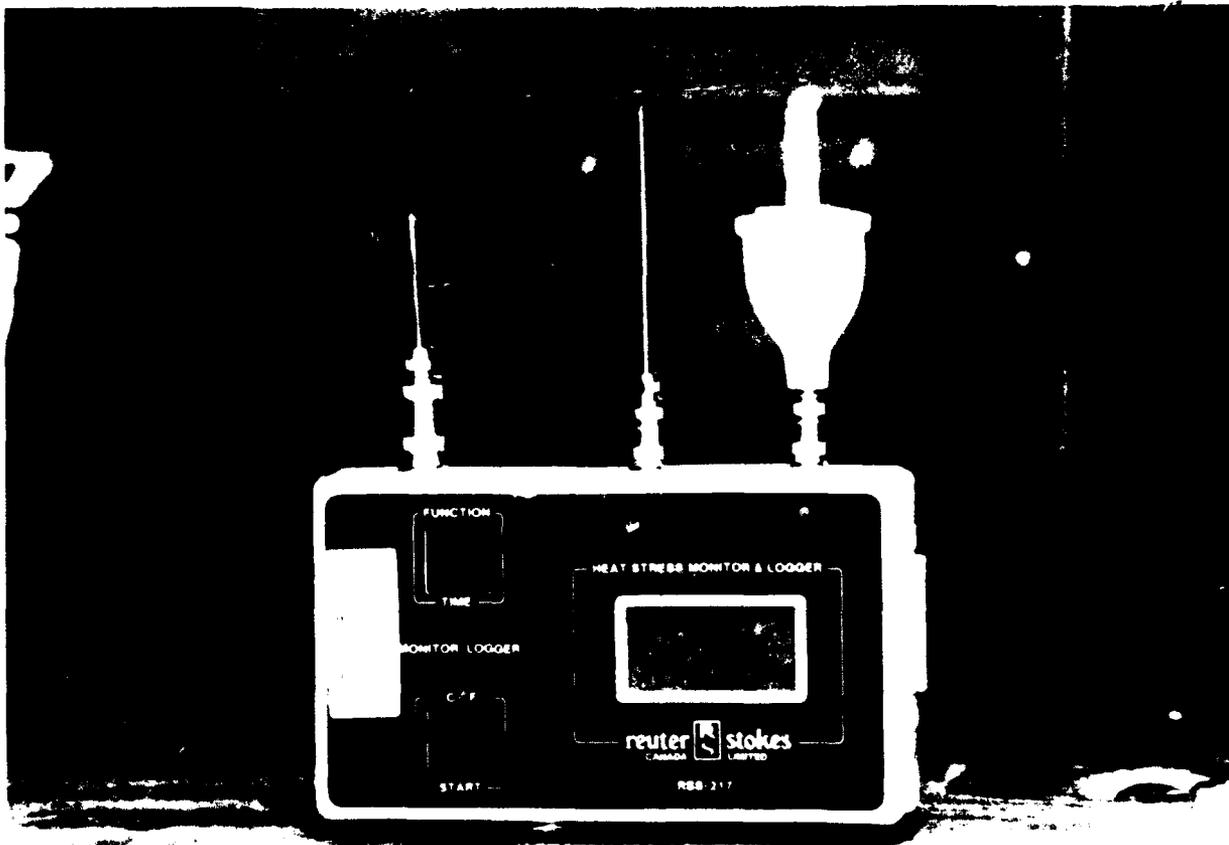
Figure 3. Door-mounted Wibget.

measurements at pilot's head height were taken instead, on the ground at the beginning and end of each flight, and the mean of the two recorded in the database. The measurements were taken only during the first cycle of summer months in which recordings were made.

Flight profile

Different types of flight maneuver will affect the cockpit conditions, depending principally on altitude, airspeed, and orientation of the aircraft towards the sun. In a NBC threat environment, aircraft are flown with doors and windows closed to reduce the risk of introducing contaminants into the cockpit. A flight profile had to be designed, to take into account as many of these factors as possible. Three basic maneuvers were used, level cruise at 100 knots (kn), 650 feet above mean sea level (amsl); low level contour flight at 100 kn, 250 feet amsl; and a 10 feet hover. The first 5 minutes were flown on a heading of 360°, the second 5 minutes on a heading of 180°. Each maneuver was performed in turn with the door, windows, and vents open, then a second time with the cockpit closed.

The stages of flight were recorded manually by a technician, whose watch was also used to record the WBGT sensor start times. He also noted the degree of cloud cover at the start and end of each maneuver, and the reading from the pilot's outside air temperature (OAT) gauge. The data sheet used to record the manually recorded information is reproduced at Appendix B.

Timing of the flight was critical to achieve consistency and maximum solar radiation conditions. Takeoff was timed so that the halfway point of the flight should occur as closely as possible to the sun's zenith.

Data analysis

On returning to the laboratory, the data from the WBGT sensors were downloaded onto a personal computer. A BASIC program was written to extract the relevant information from the data files and create a separate file for further analysis, including the manually recorded results.   A copy of the program is included at Appendix C. The mean of the last 5 minutes of recordings for each maneuver was determined.   The SAS/STAT* GLM and CORR*procedures were used for the statistical analyses. SPSS Graphics* was used to draw scatter plots for four of the flight segments. Separate graphs have not been included for the two

cruise segments, as they were so similar to those for the corresponding contour segments.

The data collected in the rear of the aircraft were similar to those from the cockpit and have therefore not been analyzed separately. Only four pairs of data were used in the final analyses, selected because of ready availability in the field, or particular interest in future simulations: cockpit WBGT with High Falls WBGT, cockpit WBGT with OAT, cockpit T_{db} with High Falls T_{db}, and cockpit T_{db} with OAT. Regression analysis was conducted for these pairs to determine the equation which could be used to predict the cockpit value from the other. Relative humidity data were calculated from a psychrometric chart for the worst condition only, the hover with cockpit closed.

Results

Data were recorded on 27 flights over a period of 22 months, and covering all months of the year except May. Data were lost on 2 of the flights because of problems with the WBGT sensors. The results are described for each of the six phases of the flight profile in turn.

Hover, cockpit closed

The hover, cockpit closed phase represents the worst case condition when the helicopter is near to the ground, where the air temperature is highest, with no forward speed to provide cooling, and doors, windows and vents closed to prevent air circulation. Table 1 contains correlation coefficients (r), intercept (β_0), slope (β_1) and standard error of the intercept (SE) for the four pairs of variables for which analyses were performed. The abbreviations used are: HF High Falls, C cockpit, DB dry bulb temperature. The summary statistics are contained in Table 2.

Figure 4 is a scatter plot of cockpit WBGT against the WBGT immediately outside the aircraft, at High Falls stage field. The linear regression line is drawn, together with the 95 percent confidence intervals. The equation defining the regression line is also included.

Table 1.

Regression statistics for hover, cockpit closed

===

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.901	8.284	0.806	1.926
OAT	C-WBGT	0.920	8.505	0.704	1.693
HF-DB	C-DB	0.904	6.966	0.792	2.089
OAT	C-DB	0.942	7.249	0.776	1.557

Table 2.

Summary statistics for hover, cockpit closed (°C)

==

Variable	Mean	SD	CV
COCKPIT DB	27.2600000	6.8511556	25.1326325
HIGH FALLS DB	25.6280000	7.8210997	30.5177917
COCKPIT WBGT	26.6600000	6.3659249	23.8781880
HIGH FALLS WBGT	22.7920000	7.1161741	31.2222449
OAT	25.8000000	8.3216585	32.2544903

Figure 5 is a scatter plot of cockpit WBGT against the OAT recorded at the end of the phase, Figure 6, cockpit T_{db} against High Falls T_{db}, and Figure 7, cockpit T_{db} against OAT. All combinations show a high degree of correlation.

Figure 8 is a plot of cockpit relative humidity (RH) against cockpit T_{db}. There is clearly no correlation, with most values of RH falling in a relatively narrow band between 30 and 55 percent, irrespective of temperature. The factor which does relate better to RH appears to be cloud cover, indicated by the numbers on the plot: one refers to the two measures of least cloud cover (less than 40 percent), two to the more cloudy conditions. The conclusion is that RH tends to be higher on cloudy days.

HIGH FALLS WBGT

C-WBGT=8.28+0.81*HF-WBGT
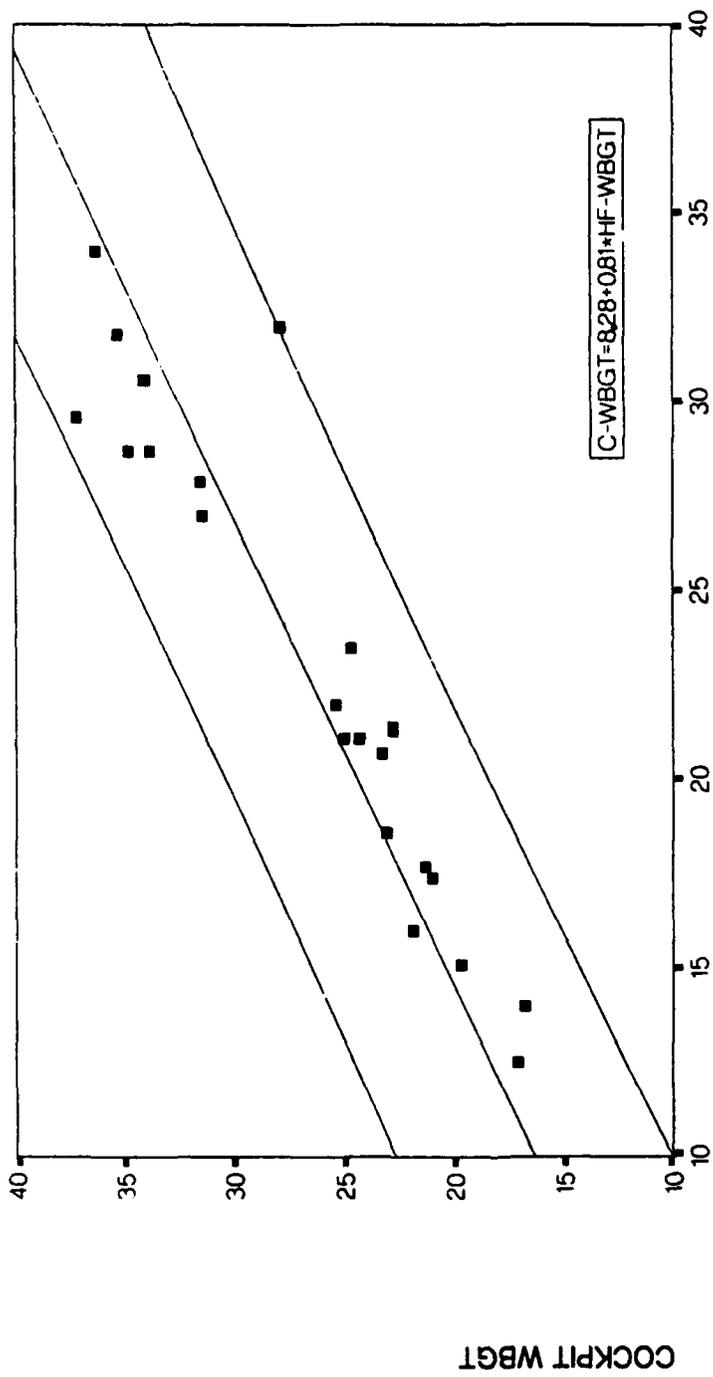
COCKPIT WBGT

Figure 4. Cockpit WBGT and High Falls WBGT, hover, cockpit closed.

OUTSIDE AIR TEMPERATURE

C-WBGT=8.51+0.70*OAT
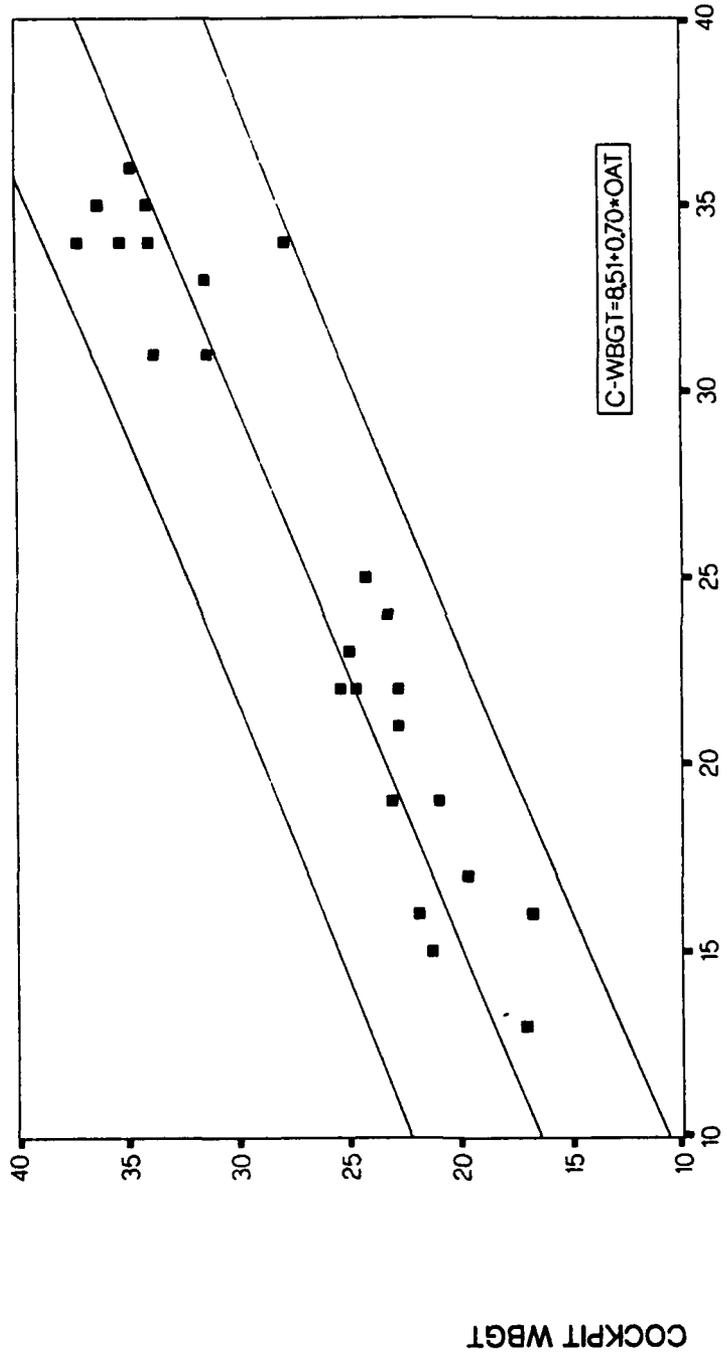
Figure 5.   Cockpit WBGT and OAT, hover, cockpit closed.

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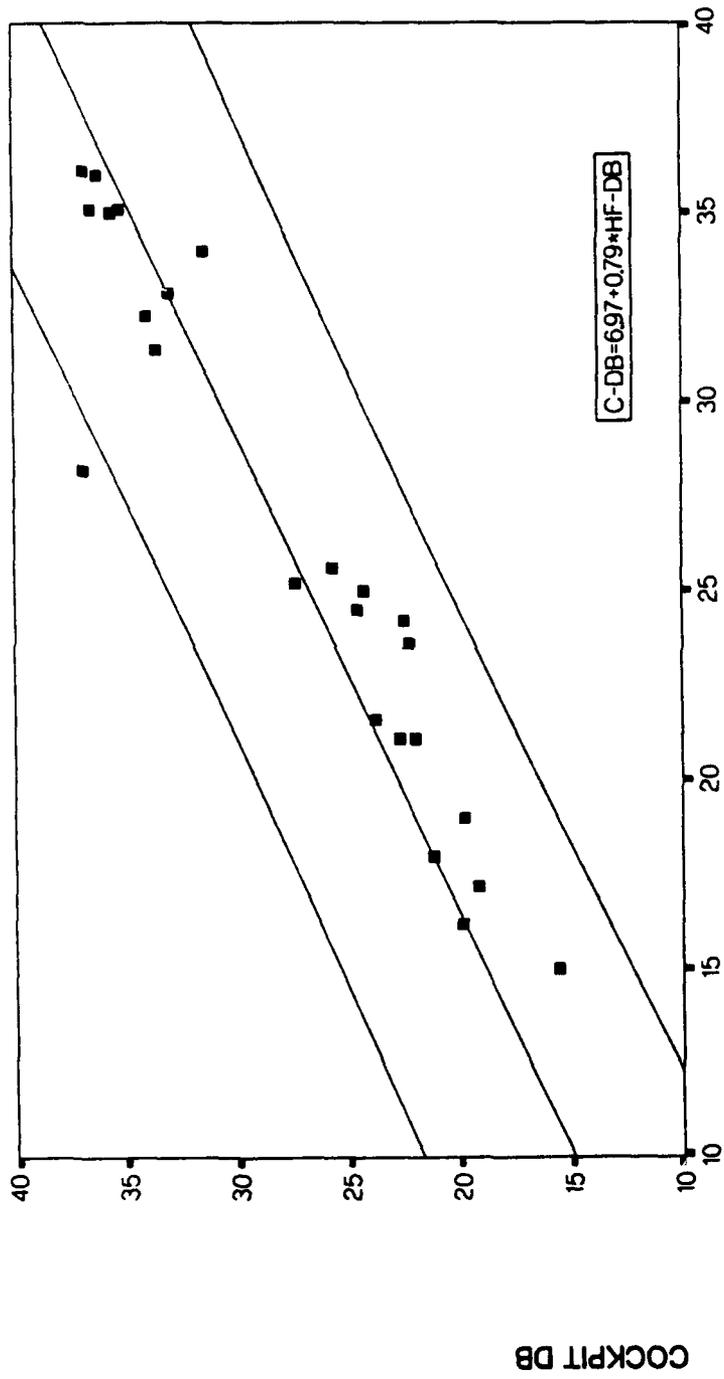
Figure 6. Cockpit T_{db} and High Falls T_{db}, hover, cockpit closed.

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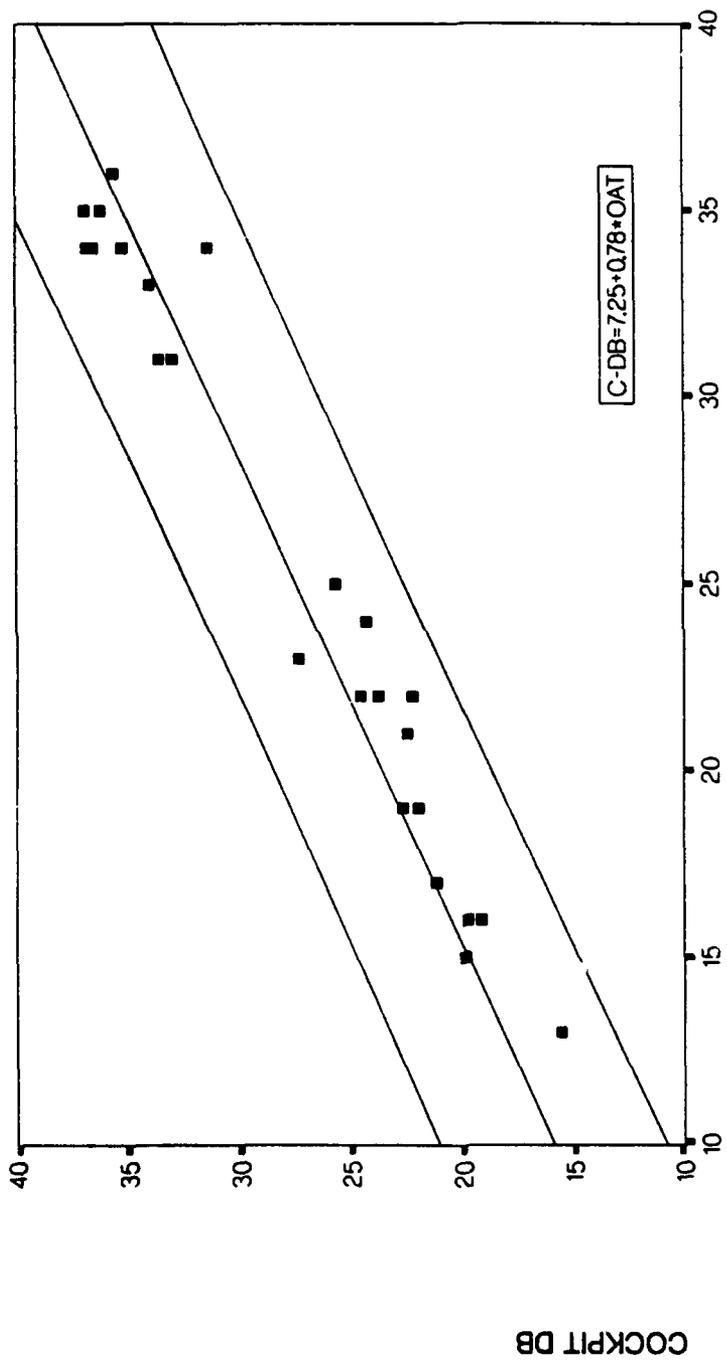
Figure 7. Cockpit T_{db} and OAT, hover, cockpit closed.

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COCKPIT DB TEMP (DEG C)
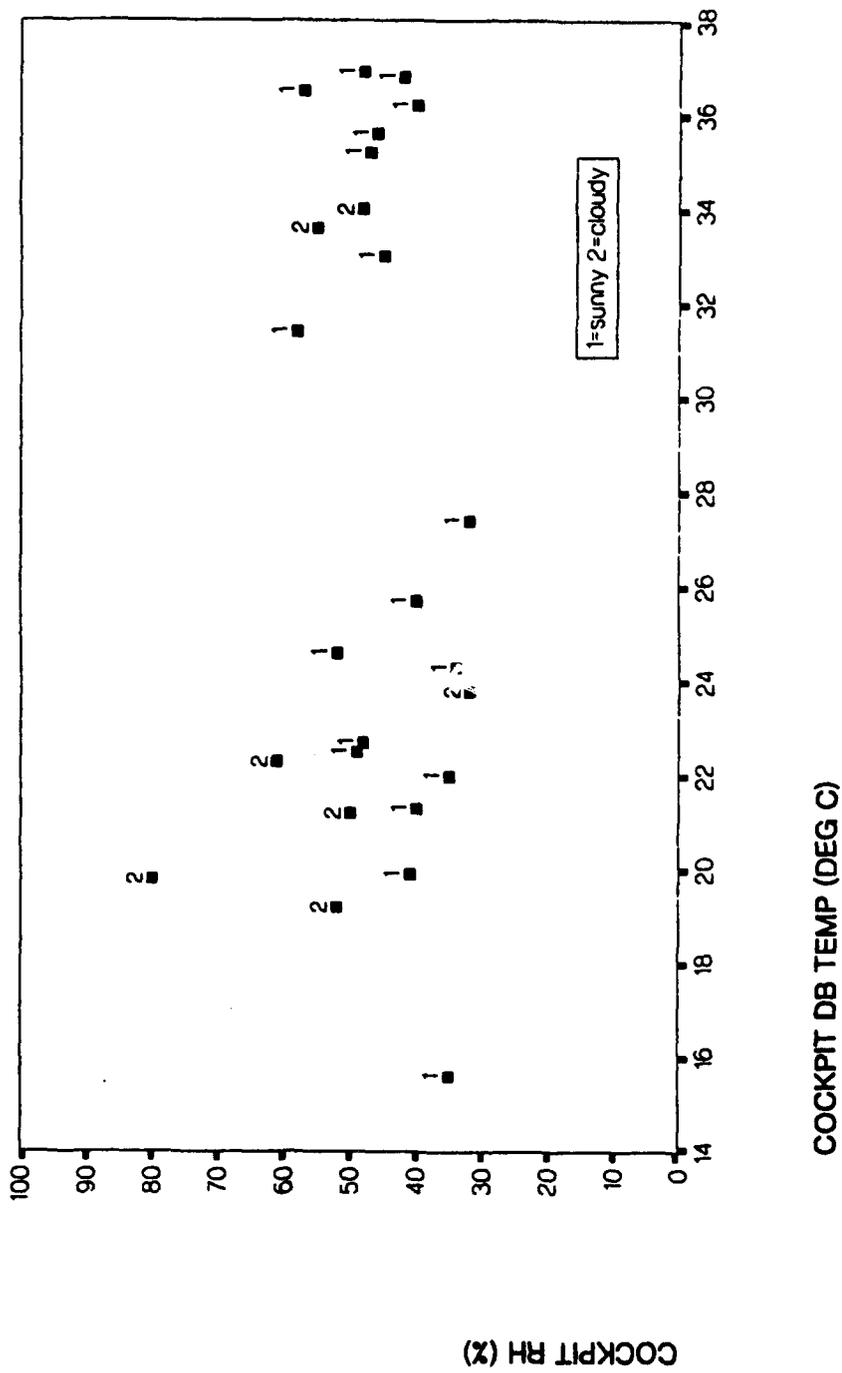
Figure 8. Cockpit RH and cockpit T_{db}, hover, cockpit closed.

Contour, cockpit closed

    Table 3 contains the regression statistics for the low level contour flight with the cockpit closed, and the summary statistics are in Table 4. Figure 9 is a scatter plot of cockpit WBGT against the High Falls WBGT.

Table 3.

Regression statistics for contour, cockpit closed
==

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.946	5.087	0.898	1.548
OAT	C-WBGT	0.962	5.924	0.827	1.233
HF-DB	C-DB	0.948	5.163	0.798	1.255
OAT	C-DB	0.969	6.676	0.811	1.086

Table 4.

Summary statistics for contour, cockpit closed (°C)
==

Variable	Mean	SD	CV
COCKPIT DB	26.2160000	6.4807844	24.7207218
HIGH FALLS DB	26.3760000	7.8294466	29.6839800
COCKPIT WBGT	25.8440000	6.6545148	25.7487802
HIGH FALLS WBGT	23.1080000	7.0077885	30.3262443
OAT	24.0800000	7.7401550	32.1435010

    Figure 10 is a scatter plot of cockpit WBGT against the OAT recorded at the end of the phase, Figure 11, cockpit T_{db} against High Falls T_{db}, and Figure 12, cockpit T_{db} against OAT. All combinations show a high degree of correlation.

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HIGH FALLS WBGT
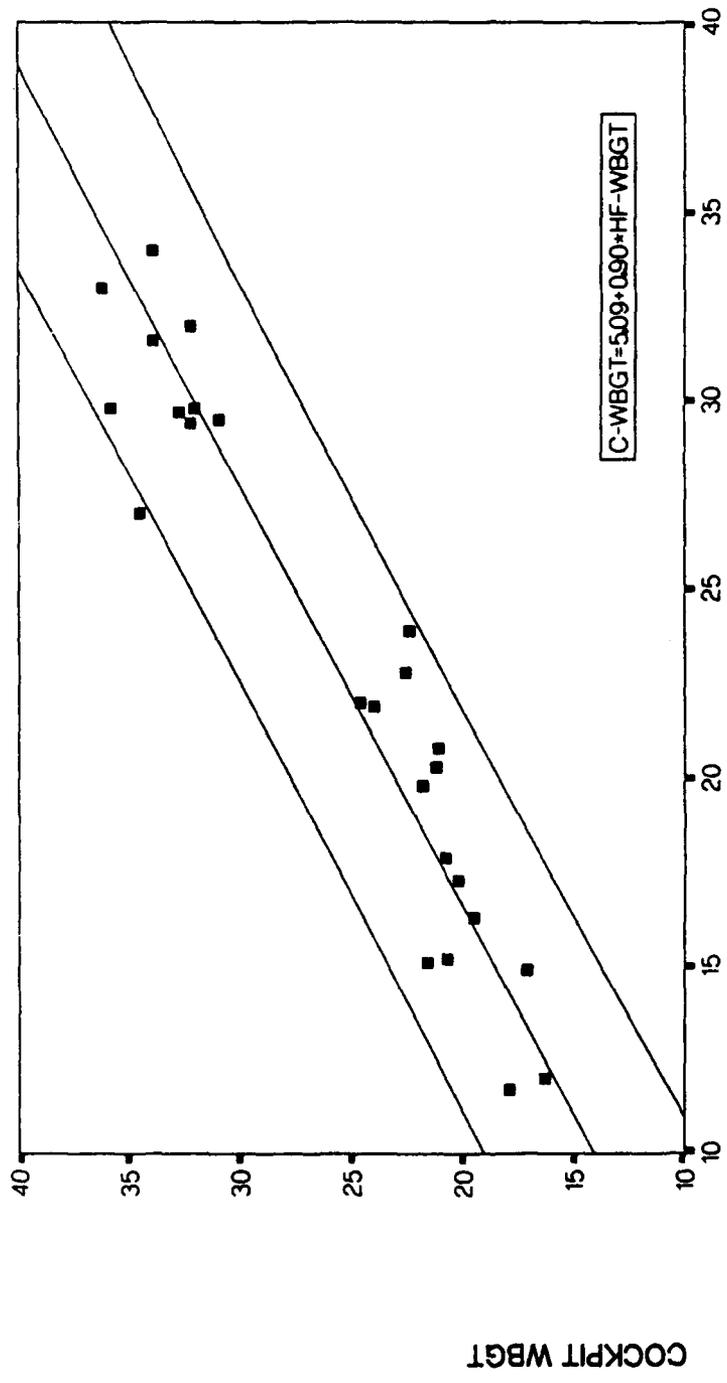
COCKPIT WBGT

C-WBGT=5.09+0.90*HF-WBGT

Figure 9. Cockpit WBGT and High Falls WBGT, contour, cockpit closed.

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OUTSIDE AIR TEMPERATURE

C-WBGT=5.92+0.83*OAT
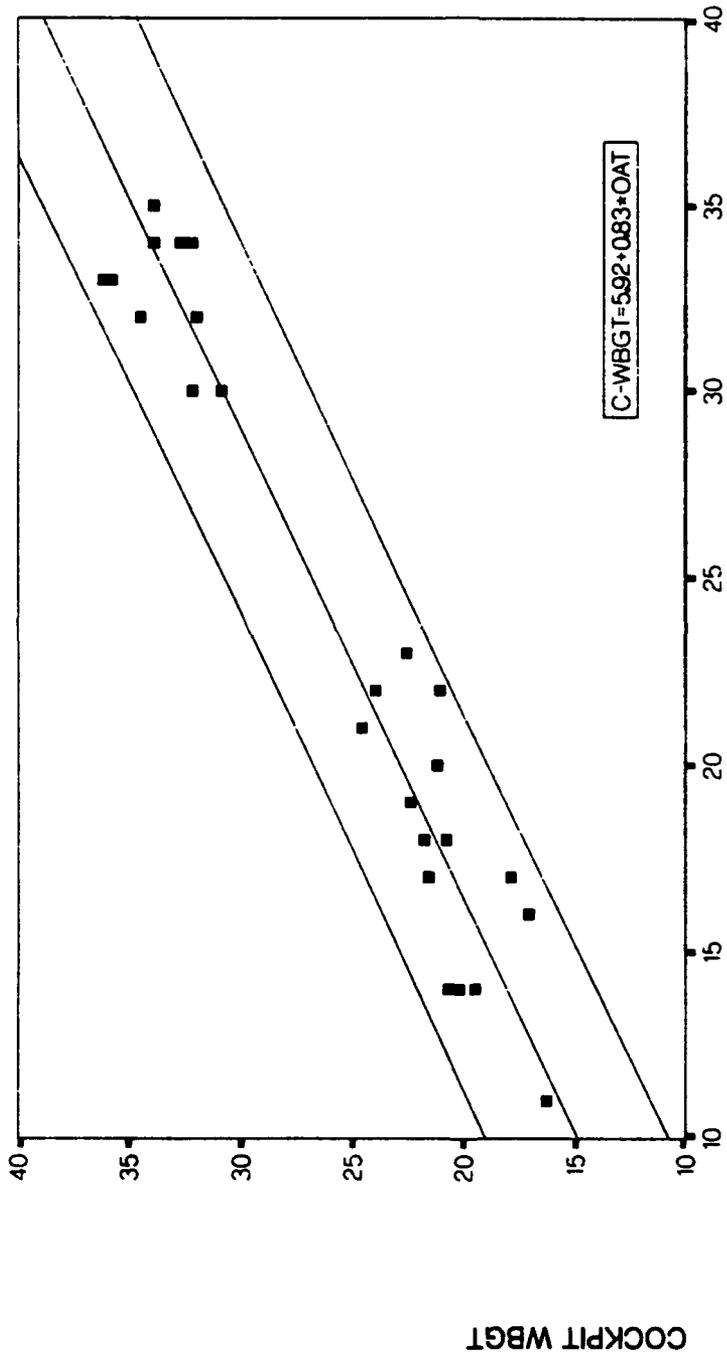
COCKPIT WBGT

Figure 10. Cockpit WBGT and OAT, contour, cockpit closed.

HIGH FALLS DB

C-DB=5.16+0.80*HF-DB
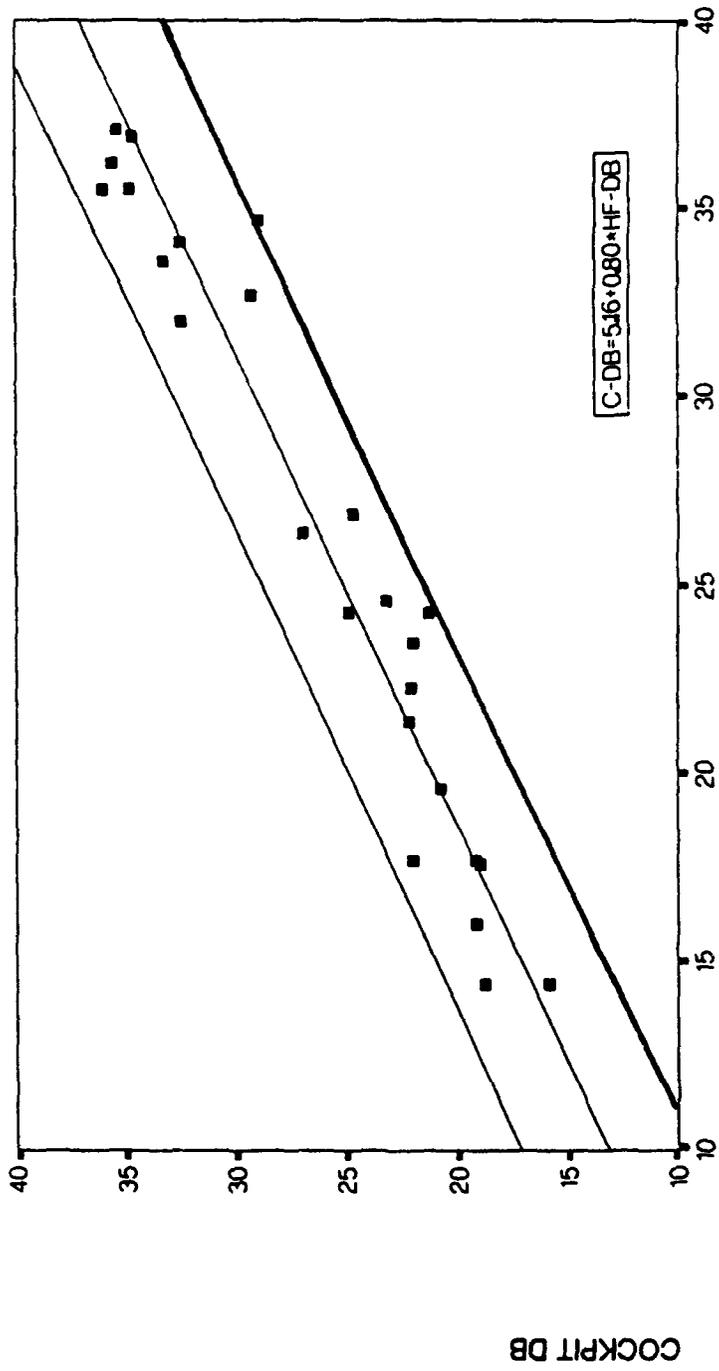
Figure 11. Cockpit T_{db} and High Falls T_{db} contour, cockpit closed.

COCKPIT DB

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Figure 12. Cockpit T_{db} and OAT, contour, cockpit closed.

C-DB=6.68+0.81*OAT

OUTSIDE AIR TEMPERATURE

COCKPIT DB

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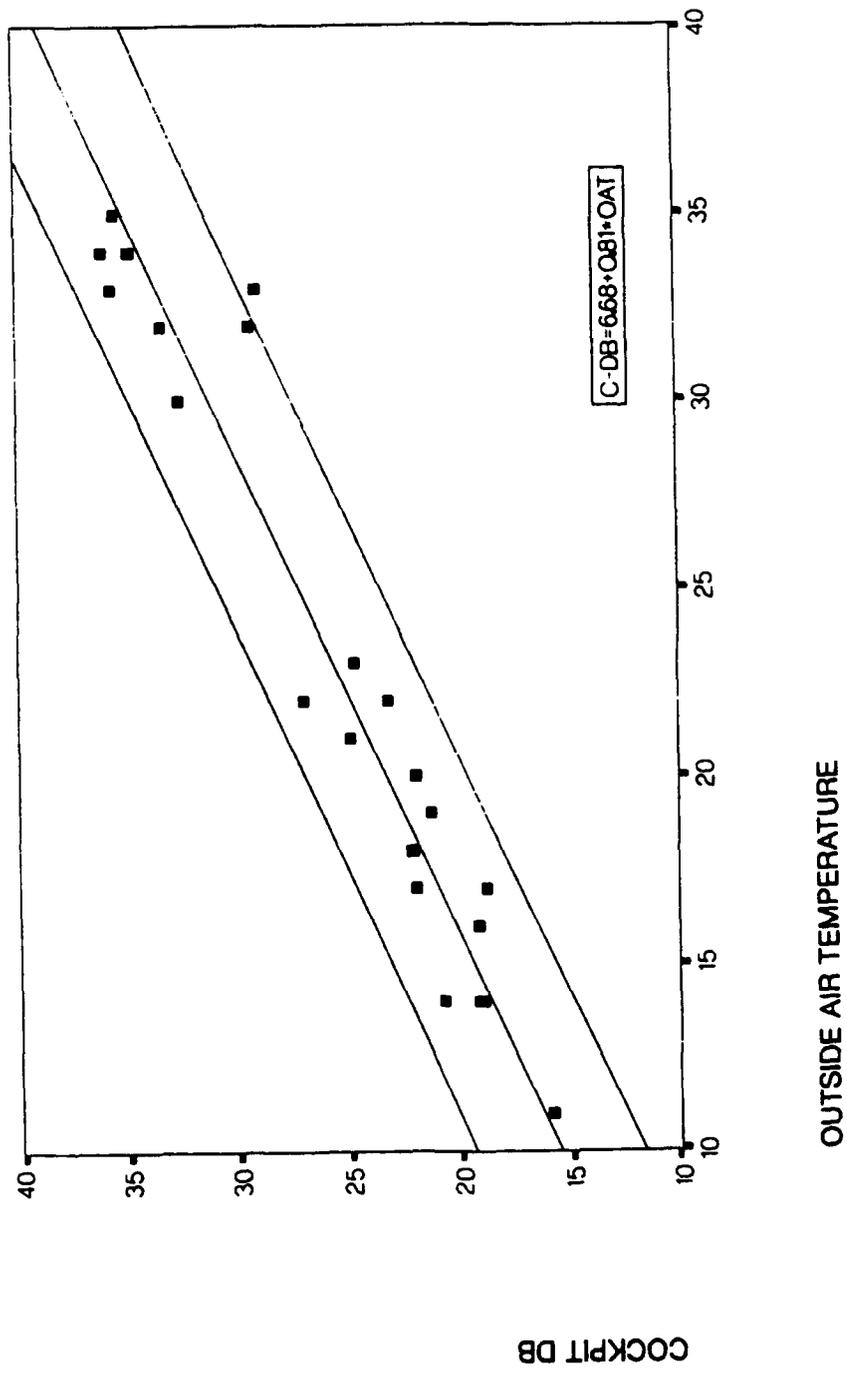
Cruise, cockpit closed

Table 5 contains the regression statistics for the cruise condition with the cockpit closed, and the summary statistics are in Table 6.

Table 5.

Regression statistics for cruise, cockpit closed

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.960	5.403	0.867	1.307
OAT	C-WBGT	0.956	6.321	0.843	1.317
HF-DB	C-DB	0.967	5.661	0.772	1.193
OAT	C-DB	0.971	7.186	0.823	1.035

Table 6.

Summary statistics for cruise, cockpit closed (°C)

Variable	Mean	SD	CV
COCKPIT DB	25.9750000	6.4660485	24.8933530
HIGH FALLS DB	26.3000000	8.0947648	30.7785734
COCKPIT WBGT	25.5750000	6.7273129	26.3042538
HIGH FALLS WBGT	23.2791667	7.4565978	32.0312061
OAT	22.8333333	7.6309819	33.4203585

Hover, cockpit open

Table 7 contains the regression statistics for hover with the cockpit open, and the summary statistics are in Table 8. Figure 13 is a scatter plot of cockpit WBGT against the High Falls WBGT.

Table 7.

Regression statistics for hover, cockpit open

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.942	5.590	0.787	1.449
OAT	C-WBGT	0.945	3.400	0.784	1.573
HF-DB	C-DB	0.967	4.785	0.836	1.259
OAT	C-DB	0.967	3.881	0.869	1.312

Table 8.

Summary statistics for hover, cockpit open (°C)

Variable	Mean	SD	CV
COCKPIT DB	26.4333333	7.0239136	26.5721826
HIGH FALLS DB	25.8833333	8.1263750	31.3961688
COCKPIT WBGT	23.7458333	6.4902589	27.3322009
HIGH FALLS WBGT	23.0583333	7.7664225	33.6816300
OAT	25.9583333	7.8212596	30.1300530

Figure 14 is a scatter plot of cockpit WBGT against the OAT recorded at the end of the phase, Figure 15 cockpit T_{db} against High Falls T_{db}, and Figure 16 cockpit T_{db} against OAT. All combinations show a high degree of correlation.
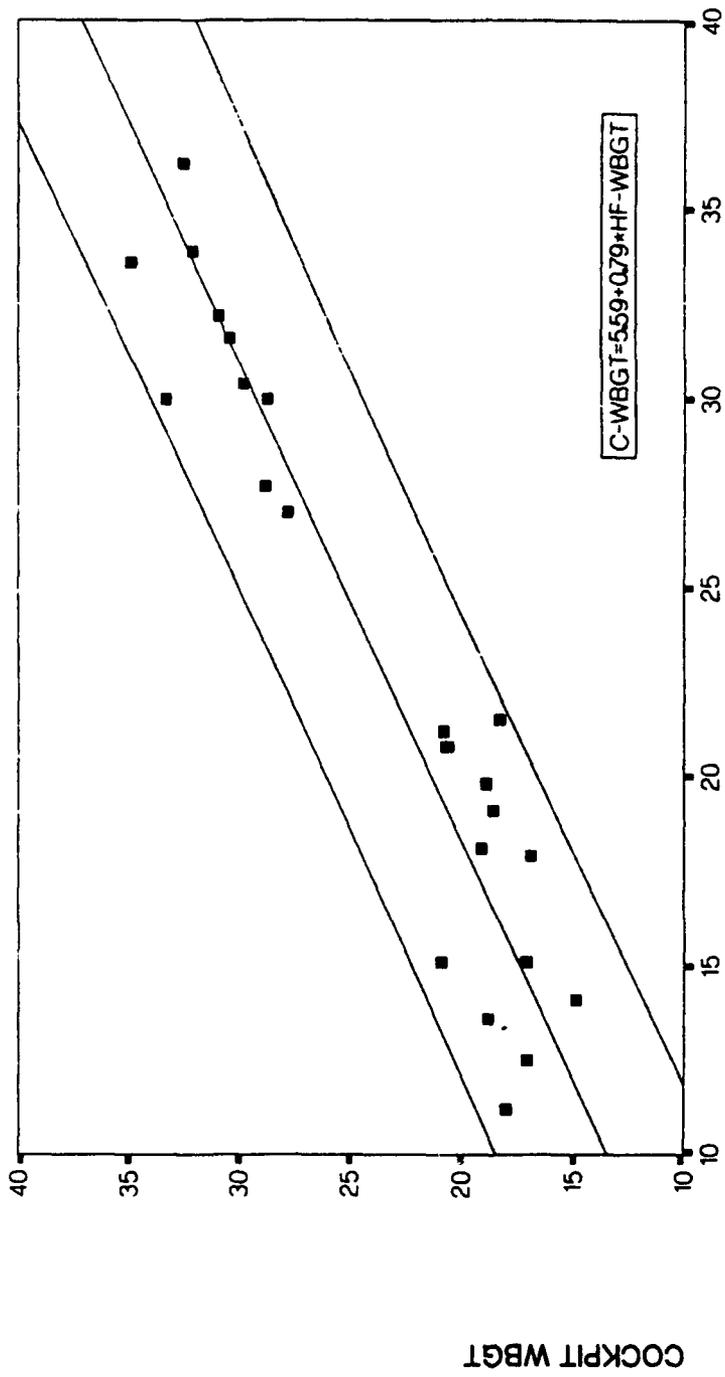
Figure 13. Cockpit WBGT and High Falls WBGT, hover, cockpit open.

C-WBGT=5.59+0.79*HF-WBGT

HIGH FALLS WBGT

COCKPIT WBGT

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OUTSIDE AIR TEMPERATURE
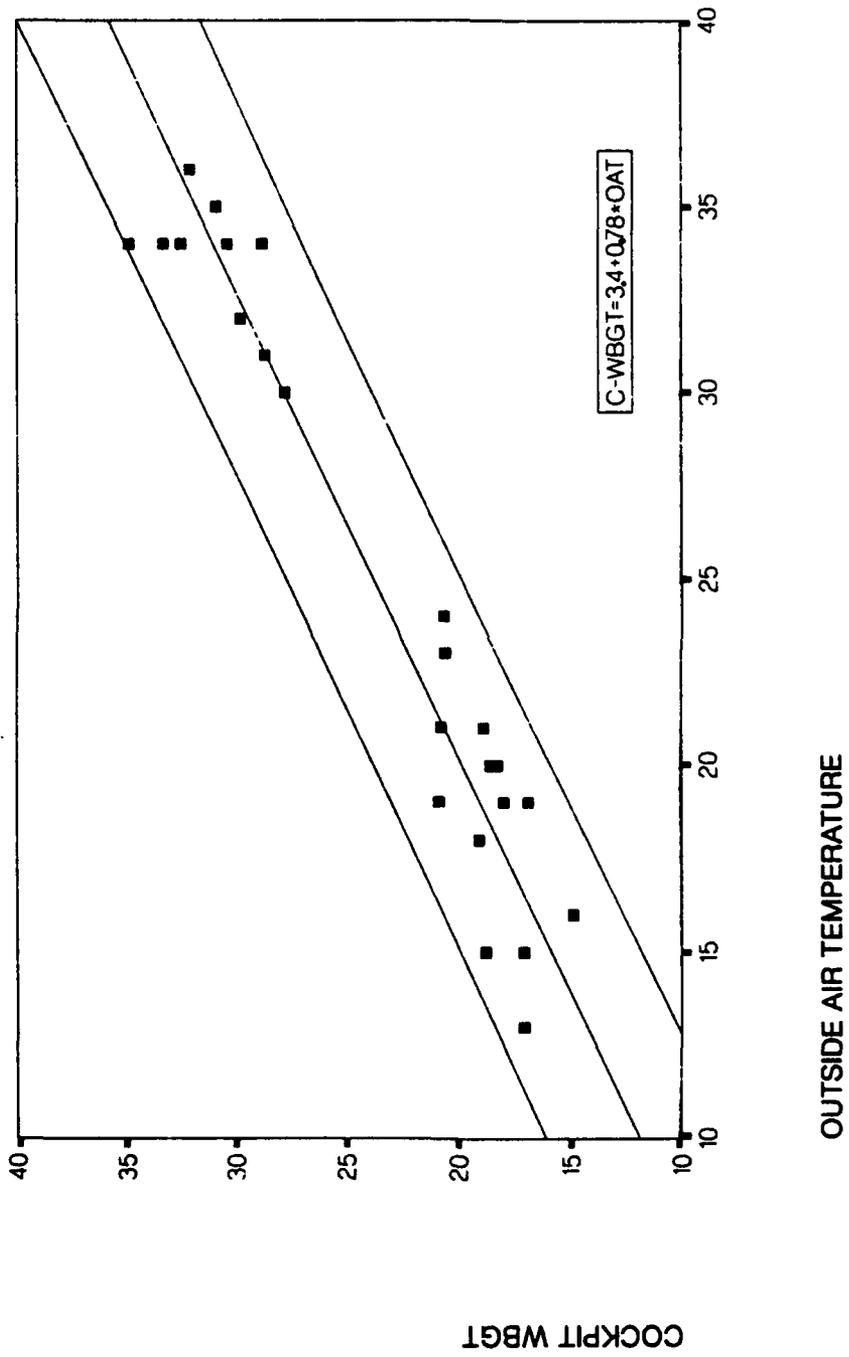
Figure 14. Cockpit WBGT and OAT, hover, cockpit open.

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HIGH FALLS DB

C-DB=4.79+0.84*HF-DB
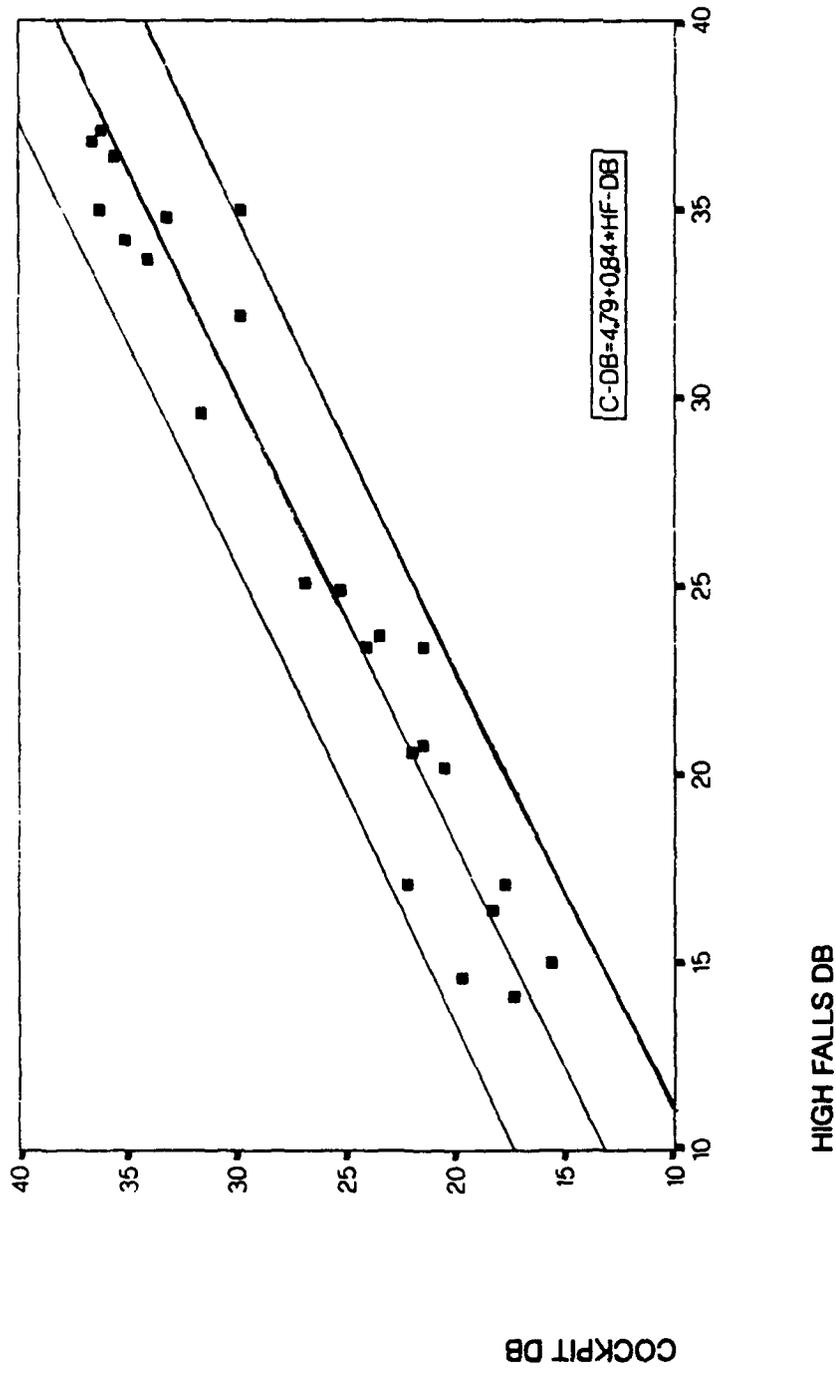
Figure 15. Cockpit T_{db} and High Falls T_{db}, hover, cockpit open.
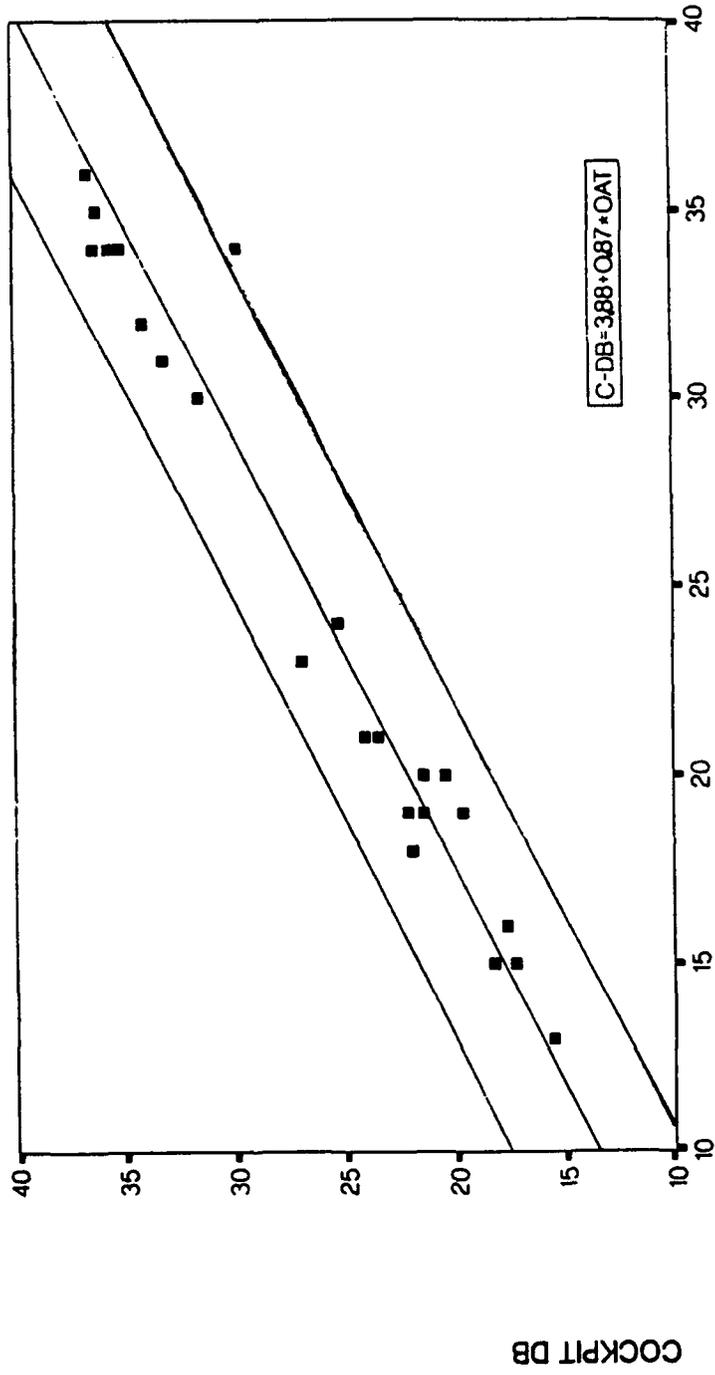
Figure 16. Cockpit T_{db} and OAT, hover, cockpit open.

COCKPIT DB

OUTSIDE AIR TEMPERATURE

C-DB=3.88+0.87*OAT

Contour, cockpit open

Table 9 contains the regression statistics for the low level contour flight with open cockpit, and the summary statistics are in Table 10. Figure 17 is a scatter plot of cockpit WBGT against the High Falls WBGT.

Table 9.

Regression statistics for contour, cockpit open

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.938	4.164	0.793	1.529
OAT	C-WBGT	0.945	3.402	0.781	1.445
HF-DB	C-DB	0.964	4.694	0.782	1.238
OAT	C-DB	0.965	5.745	0.803	1.169

Table 10.

Summary statistics for contour, cockpit open (°C)

Variable	Mean	SD	CV
COCKPIT DB	24.9125000	6.4519840	25.8985811
HIGH FALLS DB	25.8666667	7.9589527	30.7691469
COCKPIT WBGT	22.6375000	6.4065736	28.3007115
HIGH FALLS WBGT	23.2916667	7.5758149	32.5258599
OAT	23.8750000	7.7533303	32.4746818

Figure 18 is a scatter plot of cockpit WBGT against the OAT recorded at the end of the phase, Figure 19, cockpit T_{db} against High Falls T_{db}, and Figure 20, cockpit T_{db} against OAT. All combinations show a high degree of correlation.
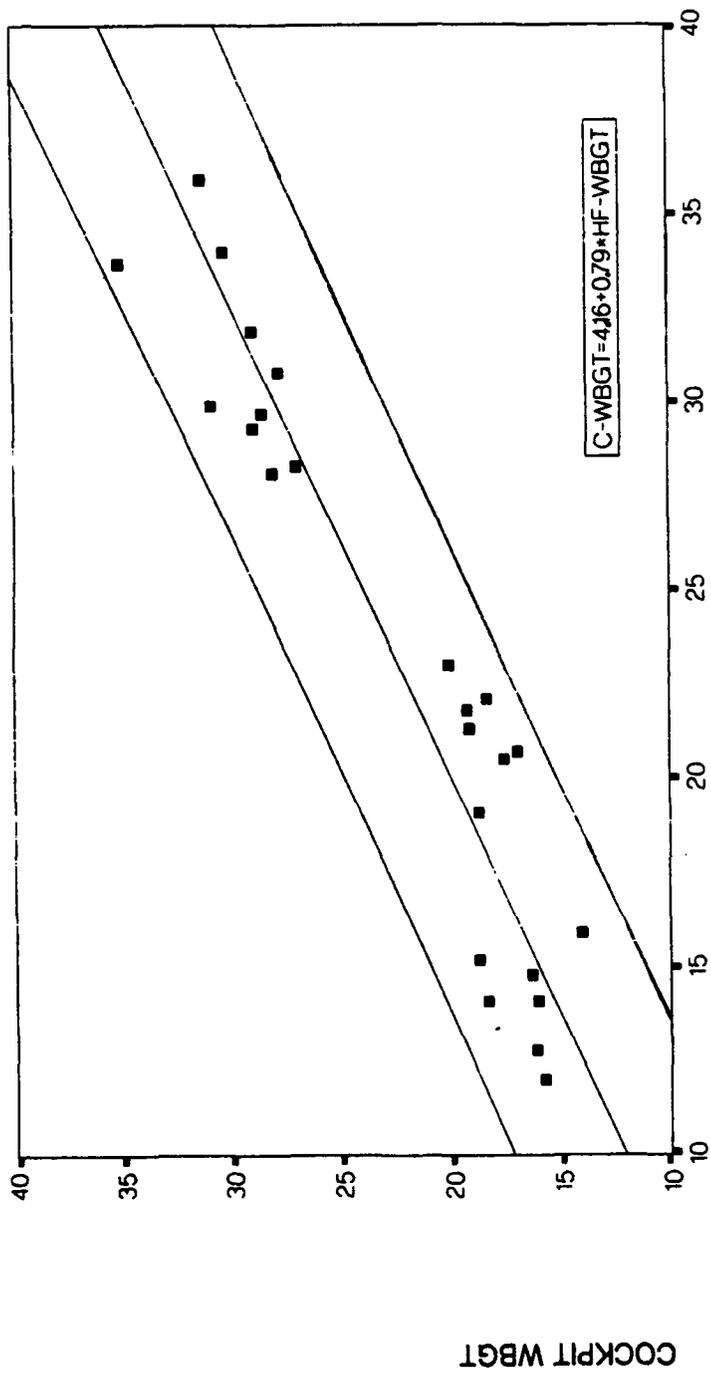
Figure 17. Cockpit WBGT and High Falls WBGT, contour, cockpit open.

HIGH FALLS WBGT

COCKPIT WBGT

C-WBGT=4.16+0.79*HF-WBGT

OUTSIDE AIR TEMPERATURE
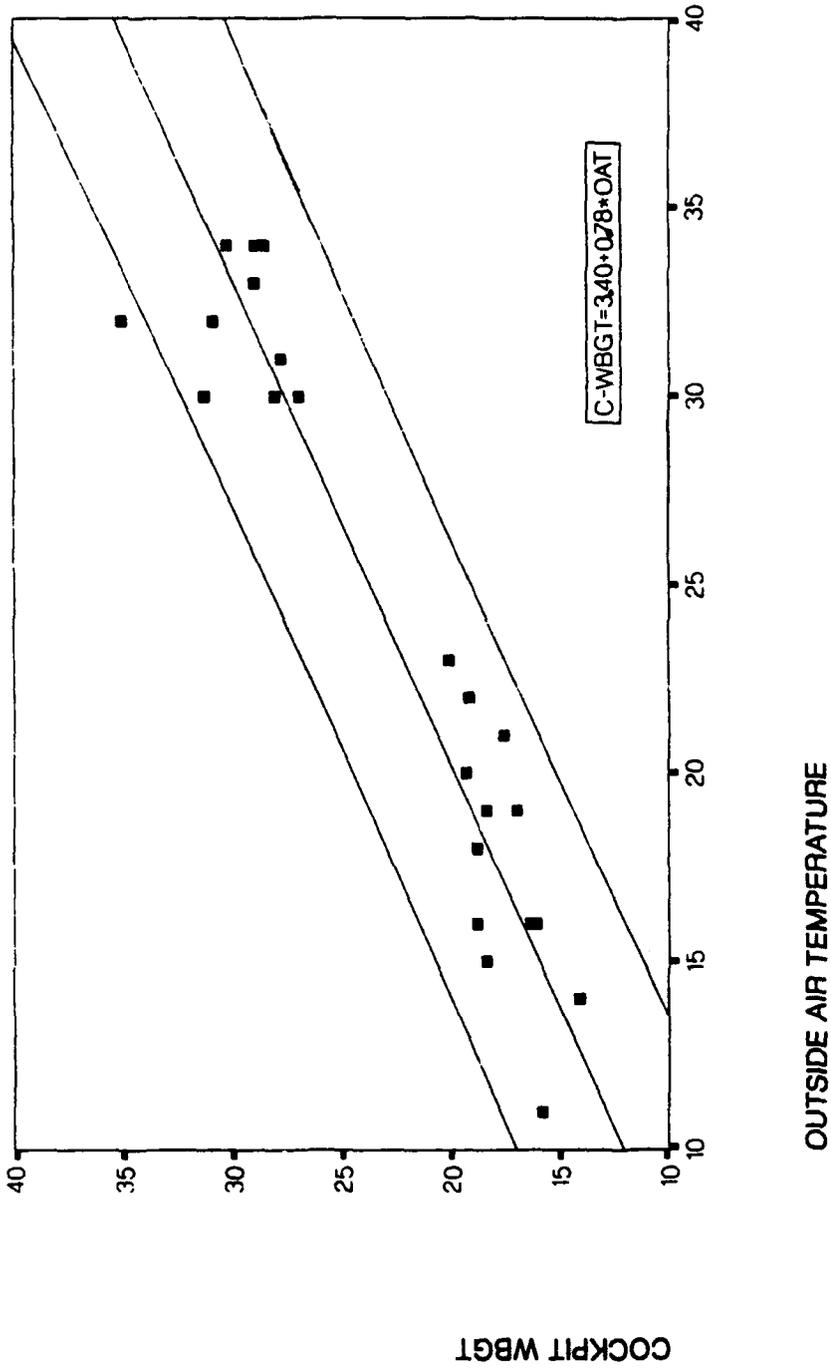
Figure 18. Cockpit WBGT and OAT, contour, cockpit open.
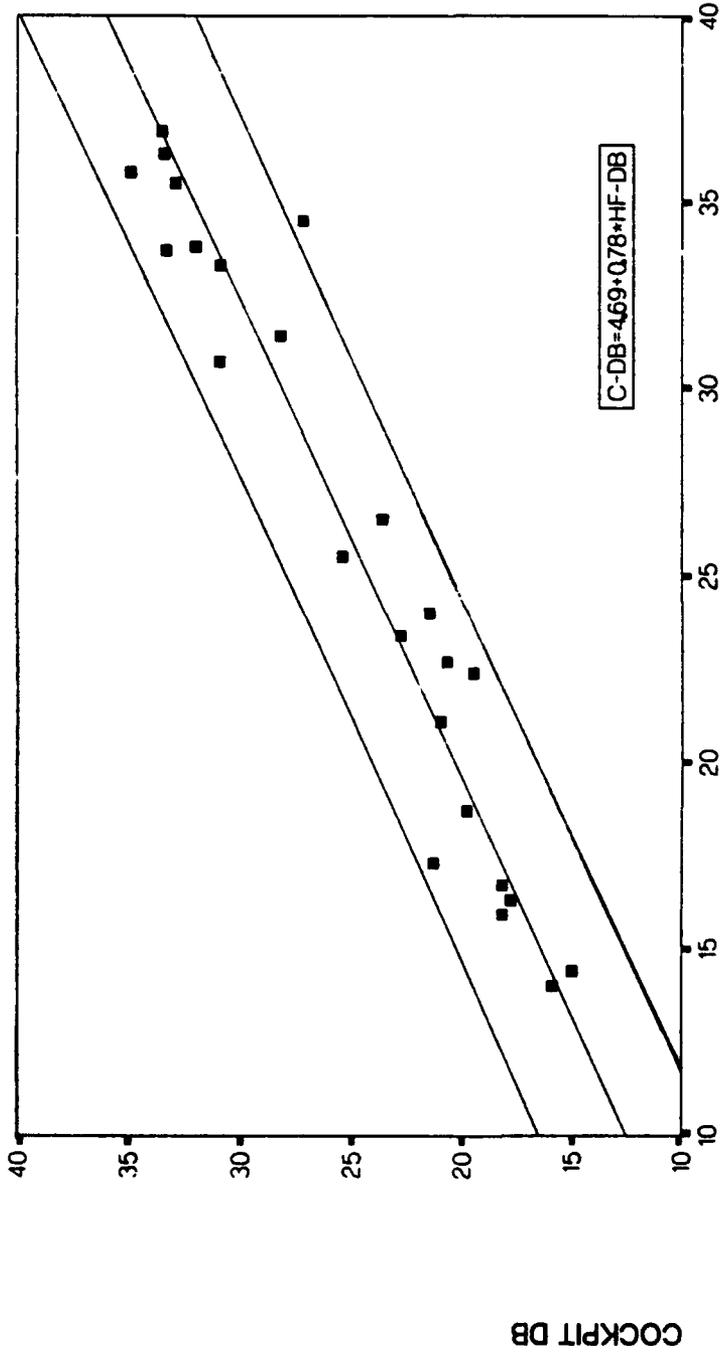
Figure 19. Cockpit T_{db} and High Falls T_{db}, contour, cockpit open.

The figure shows a scatter plot with "HIGH FALLS DB" on the horizontal axis (values 10, 15, 20, 25, 30, 35, 40) and "COCKPIT DB" on the vertical axis (values 10, 15, 20, 25, 30, 35, 40). A boxed equation appears on the plot:

$$C\text{-}DB = 4.69 + 0.78 \cdot HF\text{-}DB$$

OUTSIDE AIR TEMPERATURE

C-DB=5.74+Q80*OAT
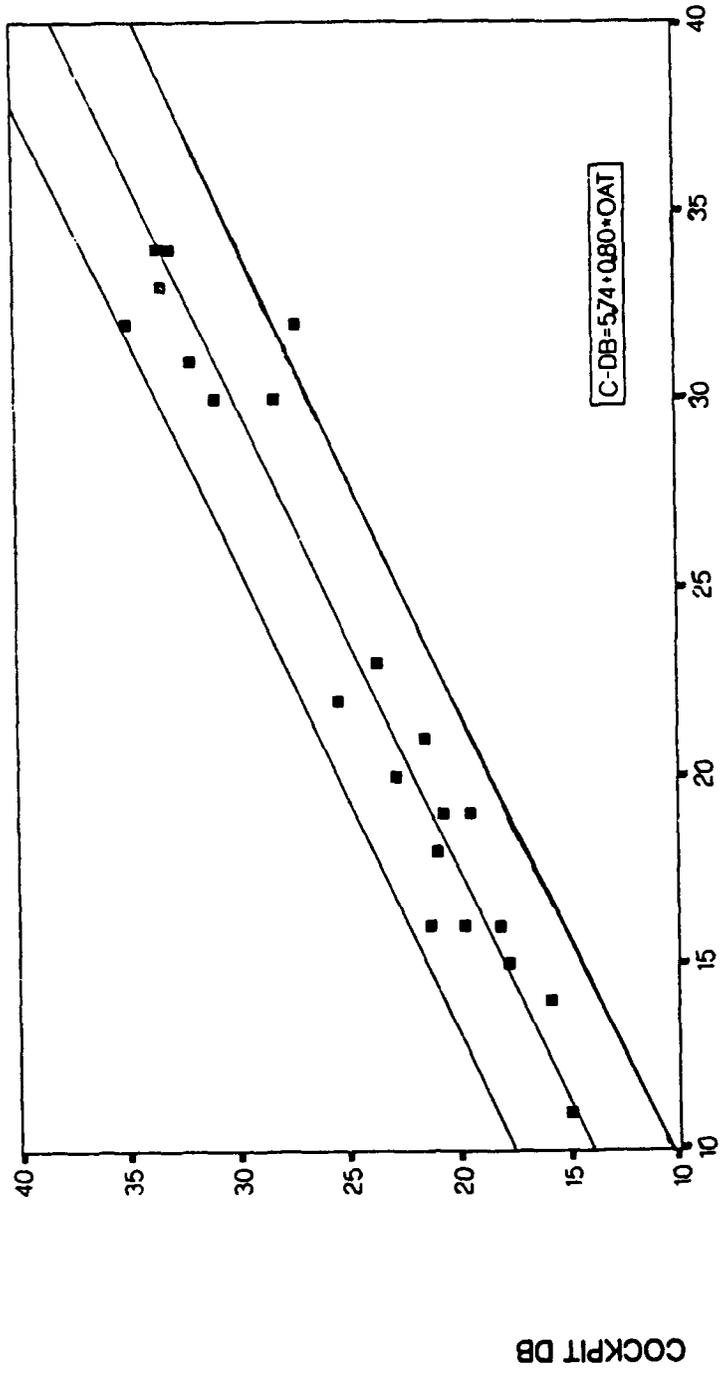
COCKPIT DB

Figure 20. Cockpit T_{db} and OAT, contour, cockpit open.

Cruise, cockpit open

Table 11 contains the regression statistics for the cruise condition with the cockpit open, and the summary statistics are in Table 12.

Table 11.

Regression statistics for cruise, cockpit open

==

x	y	r	β_0	β_1	SE
HF-WBGT	C-WBGT	0.941	4.112	0.780	1.452
OAT	C-WBGT	0.951	5.042	0.766	1.258
HF-DB	C-DB	0.970	4.645	0.764	1.091
OAT	C-DB	0.971	6.818	0.778	0.960

Table 12.

Summary statistics for cruise, cockpit open ($^\circ$C)

==

Variable	Mean	SD	CV
COCKPIT DB	24.1666667	6.1829827	25.5847561
HIGH FALLS DB	25.5416667	7.8461243	30.7189206
COCKPIT WBGT	22.1083333	6.2148431	28.1108623
HIGH FALLS WBGT	23.0625000	7.4918398	32.4849421
OAT	22.2916667	7.7149159	34.6089686

Pyranometer

The pyranometer readings, recorded before and after each flight, and converted to watts per square meter are included in Table 13. They were collected between June and October only, because maximum values were desired.

Table 13.

Pyranometer readings
(W/sq m)

Before	After
851	693
824	516
791	825
398	575
866	824
739	739
702	564
668	649
145	442
653	534

Discussion

The results for the cockpit temperature data speak for themselves, and will allow the prediction of cockpit conditions based on environmental temperature available to commanders in the field and investigators alike. They can also be used in future physiological models of the effects of heat stress on aviators, and in simulations using the USAARL UH-60 research simulator.

The RH data have been included specifically to address the issue of what levels are appropriate to use in the USAARL simulator. It is interesting to note that while almost all RH measurements were in the range 30 to 55 percent, the minimum setting of the simulator's ECS is 50 percent. This should lead to a reappraisal of the ECS specifications before future physiological studies are envisaged.

The heat flux data were also measured specifically to answer a question relating to the USAARL simulator, which was the need to reproduce the radiant heat load that is present in the

aircraft. This has now been accomplished using infrared heat lamps in the cockpit roof.

Conclusions

Equations have been derived for different flight configurations to determine the relationship between measurements available to the commander in the field and cockpit conditions. Also, appropriate levels of RH and radiant heat load have been determined for use in future simulation studies.

References

Minard, D. 1964. Effective temperature scale and its modifications. Bethesda, MD: Naval Medical Research Institute. Report No. 6.

Yaglou, C.P., and Minard, D., 1957. Control of heat casualties at military training centers. American Medical Association archives of industrial health. 16:302.

==

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==

Appendix A

Manufacturer's list

Matrix Inc. (Radiometers)
537-T South 31st Street
Mesa, AZ   85204

Reuter Stokes Canada Limited
465 Dobbie Drive
Cambridge, Ontario
Canada   N1R 5X9

SAS Institute Inc.
P.O. Box 8000
Cary, NC   27512-8000

SPSS Inc.
444 N. Michigan Avenue
Chicago, IL   60611

===

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===

Appendix B

Data collection sheet

UH-6Q COCKPIT TEMPERATURE SURVEY

INSTRUCTIONS: Complete the following information during each flight. For sky conditions, enter one of the following codes:

C - CLEAR (0-10%)	S - SCATTERED (10-40%)
B - BROKEN (40-70%)	O - OVERCAST (70-100%)
R - RAIN	

Check the remote cable plugged into the door wibget.

DATE:_____   OBSERVER:_____

PILOT:_____   CO-PILOT:_____

COCKPIT OPEN

FLIGHT PHASE	START		FINISH		SKY CONDITION
	TIME	OAT	TIME	OAT	
CRUISE 650' MSL 100kts (Hdg 360 5 min, 180 5 min)					
CONTOUR 250' MSL 100kts (Hdg 360 5 min, 180 5 min)					
HOVER 10' AGL (Hdg 360 5 min, 180 5 min)					

COCKPIT CLOSED

FLIGHT PHASE	START		FINISH		SKY CONDITION
CRUISE 650' MSL 100kts (Hdg 360 5 min, 180 5 min)					
CONTOUR 250' MSL 100kts (Hdg 360 5 min, 180 5 min)					
HOVER 10' AGL (Hdg 360 5 min, 180 5 min)					

*** Don't forget the wibget on the ground ***

WBGT START TIME_____   DEWPOINT_____

ID# COCKPIT_____   REAR_____   LITTER_____   HFG1_____   FRG1_____

Appendix C

Data reduction program

```
5   REM ***     HELI2.BAS
10  REM ***     WIBGET COMPRESSION PROGRAM         ***
20  REM ***  11 JUN 1990     CHRISTIAN WOLFF       ***
30  REM ***  28 JUN 1990       LAST REVISED        ***
40  REM *** THIS PROGRAM COMBINES DATA FROM ALL WIBGETS AND
MANUAL
50  REM ***  OBSERVATIONS FOR EACH WEEKLY TRIAL INTO A SINGLE FILE
***
60  REM
70  DIM FLAG(500), FLAG2(500)
80  DIM L$(5), A$(255,7) , E$(2), SKY$(7),  ATE$(8)
90  DIM J$(20)
100 DIM THAT(6,11,5,3), THIS(6), OATS(6), OATF(6)
110 KEY OFF
120 VX=  0: VY= 0
130 SKY= 0
140 L$(1)="C"
150 L$(2)="L"
160 L$(3)="R"
170 L$(4)="G1"
180 L$(5)="G2"
190 CLS
200 PRINT " THIS PROGRAM COMBINES DATA FROM ALL WIBGETS AND
MANUAL"
210 PRINT   "OBSERVATIONS FOR EACH WEEKLY TRIAL INTO A SINGLE
FILE"
220 PRINT:PRINT: PRINT" WHICH WEEK'S DATA IS TO BE PROCESSED?"
230 INPUT E$
240 IF LEN(E$)>2 THEN PRINT" ONLY TWO NUMBERS PLEASE":GOTO 220
250 PRINT:INPUT " DATE OF DATA? (MMDDYY)"; ATE$
260 IF LEN(ATE$)<>6 THEN PRINT" SIX NUMBERS PLEASE":GOTO 250
270 IF VAL(LEFT$(ATE$,2))>12 THEN PRINT "TOO MANY MONTHS ": GOTO
250
280 IF VAL(MID$(ATE$,3,2))>31 THEN PRINT "TOO MANY DAYS": GOTO
250
290 PRINT:INPUT "PYRANOMETER READINGS? ",PYRO:PRINT:INPUT
"DEWPOINT? ",DEW
300 PRINT:PRINT "ENTER WBGT START TIME ":GOSUB 2370
310 ST = MINS
320 PRINT:PRINT" *******   NORMAL OPERATIONS   *******":PRINT
330 PRINT "ENTER CRUISE START TIME": GOSUB 2370
340 THIS(1)=MINS : PRINT
350 PRINT "ENTER CONTOUR START TIME": GOSUB 2370
360 THIS(2)=MINS : PRINT
370 PRINT "ENTER HOVER START TIME": GOSUB 2370
380 THIS(3)=MINS : PRINT
390 PRINT:PRINT" ******* NBC OPERATIONS *******":PRINT
400 PRINT "ENTER CRUISE START TIME": GOSUB 2370
410 THIS(4)=MINS : PRINT
420 PRINT "ENTER CONTOUR START TIME": GOSUB 2370
430 THIS(5)=MINS : PRINT
```

```
440 PRINT "ENTER HOVER START TIME": GOSUB 2370
450 THIS(6)=MINS : PRINT
460 REM
470 REM   **** TIME TO LOAD THE DATA FROM DISK ***
480 REM
490 GOSUB 1990
500 FOR G= 1 TO 5
510 OPEN "W"+E$+L$(G)+".WIB" FOR INPUT AS #1
520 X=0
530 X=X+1
540 FOR Y = 1 TO 7
550 IF EOF(1)=-1 THEN ED=X: GOTO 590
560 INPUT #1, A$(X,Y)
570 NEXT Y
580 IF X < 255 THEN GOTO 530
590 CLOSE #1
600 REM
610 REM **** THIS SECTION DIVIDES THE DATA BY FLIGHT PROFILE
620 REM **** AND REORGANIZES IT INTO FORM FOR COMPACT STORAGE
630 REM
640 FOR A= 1 TO 6
650 B = 0
660 DUR = THIS(A) -   ST
670 FOR Z = DUR TO (DUR +   9)
680 B = B + 1
690 THAT (A,B,G,1) = VAL(A$(Z,3))
700 THAT (A,B,G,2) = VAL(A$(Z,4))
710 THAT (A,B,G,3) = VAL(A$(Z,7))
720 NEXT Z
730 SUM = 0
740 FOR V = 1 TO 3
750 FOR Z= 5 TO 10
760 SUM = (THAT(A,Z,G,V) + SUM)
770 NEXT Z
780 THAT (A,11,G,V) = SUM/6
790 SUM = 0 : NEXT V
800 PUT(VX,VY),FLAG2,AND
810 VX=VX+ 18:VY=VY+ 6
820 PUT(VX,VY),COPTER
830 SOUND 100+VX,2
840 NEXT A
850 NEXT G
860 REM *** RETURNS NORMAL TIME STUFF ***
870 FOR I = 1 TO 6
880 TEM=FIX(THIS(I)/60)
890 THIS(I)= TEM*100 + (THIS(I) - TEM*60)
900 NEXT I
910 REM
920 REM *** THIS SECTION CREATES A NEW COMPACT FILE ***
930 OPEN "WEEK"+E$+".DAT" FOR OUTPUT AS #2
940 WRITE #2,ATE$,E$,DEW,PYRO
```

```
950 FOR T= 1 TO 6
960 FOR D = 1 TO 5: FOR V = 1 TO 3
970    WRITE #2, THAT(T,1,D,V); THAT(T,2,D,V); THAT(T,3,D,V);
THAT(T,4,D,V); THAT(T,5,D,V);THAT(T,6,D,V); THAT(T,7,D,V);
THAT(T,8,D,V);THAT(T,9,D,V);THAT(T,10,D,V);THAT(T,11,D,V)
980 NEXT V
990 PUT(VX,VY),FLAG2,AND
1000 VX=VX -4.5:VY=VY+2.2
1010 PUT(VX,VY),COPTER
1020 SOUND 100+VX,2
1030 NEXT D
1040    WRITE #2, SKY$(T), OATS(T), OATF(T)
1050 NEXT T
1060 CLOSE #2
1070 INPUT "DO YOU WANT A HARD COPY?",AN$
1080 IF AN$ <> "Y" THEN 1800
1090 REM
1100 REM *** HARD COPY ROUTINE ***
1110 REM
1120 J$(1) = "    COCKPIT" : J$(2) = "    LITTER " : J$(3) = "
REAR    "
1130 J$(4) = "    GROUND1" : J$(5) = "    GROUND2"
1140 LPRINT:LPRINT
1150 LPRINT"                              UH-60 TEMPERATURE STUDY"
1160 LPRINT"                              FLIGHT SUMMARY"
1170 LPRINT
1180 LPRINT "    DATE: ";
LEFT$(ATE$,2);"/";MID$(ATE$,3,2);"/";RIGHT$(ATE$,2),"
TRIAL NO. ";E$
1190 LPRINT
1200 LPRINT "    DEWPOINT:";DEW,"              PYRANOMETER:";PYRO
1210 LPRINT:LPRINT
1220 LPRINT "                              NORMAL
OPERATIONS":LPRINT
1230 LPRINT "              CRUISE              CONTOUR
              HOVER"
1240 LPRINT
1250 FOR K = 1 TO 5
1260 LPRINT J$(K);"    ";
1270 FOR P = 1 TO 3
1280 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,1);
1290 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,2);
1300 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,3);
1310 LPRINT "     ";
1320 NEXT P : LPRINT :NEXT K
1325 LPRINT "    OATS          ";
1330 FOR P = 1 TO 3
1340 LPRINT USING "##.#";OATS(P);
1350 LPRINT "              ";
1360 NEXT P:LPRINT
1370 LPRINT "    OATF          ";
```

```
1380 FOR P = 1 TO 3
1390 LPRINT USING "##.#";OATF(P);
1400 LPRINT "                    ";
1410 NEXT P:LPRINT
1420 LPRINT "     SKIES          ";
1430 FOR P = 1 TO 3
1440 LPRINT SKY$(P);"                              ";
1450 NEXT P :LPRINT
1460 LPRINT "     TIME          ";
1470 FOR P = 1 TO 3
1480 LPRINT USING "####";THIS(P);
1490 LPRINT "                    ";
1495 NEXT P:LPRINT
1500 LPRINT:LPRINT
1510 LPRINT "                                              CLOSED
OPERATIONS":LPRINT
1520 LPRINT
1530 FOR K = 1 TO 5
1540 LPRINT J$(K);"     ";
1550 FOR P = 4 TO 6
1560 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,1);
1570 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,2);
1580 LPRINT "   ";:LPRINT USING "##.#"; THAT(P,11,K,3);
1590 LPRINT "        ";
1600 NEXT P : LPRINT :NEXT K
1610 LPRINT "     OATS          ";
1620 FOR P = 4 TO 6
1630 LPRINT USING "##.#";OATS(P);
1640 LPRINT "                    ";
1650 NEXT P:LPRINT
1660 LPRINT "     OATF          ";
1670 FOR P = 4 TO 6
1680 LPRINT USING "##.#";OATF(P);
1690 LPRINT "                    ";
1700 NEXT P:LPRINT
1710 LPRINT "     SKIES          ";
1720 FOR P = 4 TO 6
1730 LPRINT SKY$(P);"                              ";
1740 NEXT P :LPRINT
1750 LPRINT "     TIME          ";
1760 FOR P = 4 TO 6
1770 LPRINT USING "####";THIS(P);
1780 LPRINT "                    ";
1790 NEXT P
1800 PSET(298,270)
1810 DRAW "U92"
1820 FOR T = 270 TO 180 STEP -1
1830 PUT(300,T),FLAG
1840 FOR W = 1 TO 20:NEXT W
1850 PUT(300,T),FLAG2,AND
1860 NEXT T
```

```
1870 PUT(300,T),FLAG
1880 SOUND 587,10
1890 FOR U = 1 TO 940:NEXT U
1900 FOR Y = 1 TO 6
1910 SOUND 293,9
1920 FOR U = 1 TO 440:NEXT U
1930 SOUND 293,0
1940 FOR U = 1 TO 240:NEXT U
1950 NEXT Y
1960 SOUND 293,0
1970 SOUND 587,10
1980 END
1990 SCREEN 9,0:COLOR 9,1:CLS: KEY OFF
2000 DIM COPTER(592), BOXES(92)
2010 REM  *** HELICOPTER DRAW
2020 REM *** COPTERS COURTESY OF BRETT FOREHAND
2030 DRAW "BM 0,0 BR 55 TA 7 L 55"
2040 DRAW "TA -64 BR 9 TA 30 R 9 TA 15 R 10"
2050 DRAW "TA 21 BL 17 TA 0 R 12 TA 60 R 9"
2060 DRAW "TA 0 R 4 BL2 U 2"
2070 DRAW "BD 2 BR 2 TA -67 R 8 TA 10 R 23"
2080 DRAW "TA 50 R 5 TA 0 R2 TA 55 L4"
2090 DRAW "TA 10 R 2 D 1 TA 20 L40"
2100 DRAW "TA -17 L 16 TA0 U 3"
2110 DRAW "TA -54 BR 14 TA0 R 19"
2120 DRAW "BL 3 TA -45 L 6 BR 6"
2130 DRAW "TA 0 BL 14 TA 45 R 5"
2140 DRAW "BR 5 "
2150 GET(0,0)-(60,22),COPTER
2160 CLS
2170 LINE (50,50)-(70,60),2,BF
2180 FOR T =50 TO 60 STEP 2:PSET (50,T):DRAW "R20":NEXT T
2190 LINE (50,50)-(58,54),6,BF
2200 GET(50,50)-(70,60),FLAG
2210 LINE (100,50)-(160,90),0,BF
2220 GET(100,50)-(160,90),FLAG2
2230 CLS
2240 CIRCLE (130,270),100,,0,3.1483
2250 PSET(230,270): DRAW "L200"
2260 PAINT (180,240)
2270 LINE(115,255)-(145,270),1,BF
2280 LINE(65,225)-(195,240),1,BF
2290 PSET(78,227):DRAW "D11 R12 U11"
2300 PSET(104,227):DRAW "L11 D5 R11 D6 L11"
2310 PSET(128,238):DRAW "H10 G10 BE5 R9"
2320 PSET(152,238):DRAW "H10 G10 BE5 R9"
2330 PSET(154,238):DRAW "U11 R11 D5 L11 R3 F6"
2340 PSET(168,227):DRAW "D11 R11"
2350 RETURN
2360 END
2370 REM *** TIME CONVERSION SEQUENCE ***
```

```
2380 INPUT TIME
2390 T1 = INT(TIME/100)
2400 HM = T1 * 60
2410 IF T1>24 THEN PRINT "TOO MANY HOURS!! PLEASE REDO": GOTO
2380
2420 MM = TIME - T1*100
2430 IF MM>59 THEN PRINT "MINUTES CAN NOT EXCEED 59!! PLEASE
REDO": GOTO 2380
2440 MINS = HM + MM
2450 IF SKY < 1 THEN GOTO 2520
2460 PRINT: INPUT " OUTSIDE AIR TEMPERATURE, START ", OATS(SKY)
2470 IF (OATS(SKY))>150 THEN PRINT "INCORRECT INPUT!! PLEASE
REDO": GOTO 2460
2480 PRINT: INPUT " OUTSIDE AIR TEMPERATURE, FINISH ", OATF(SKY)
2490 IF (OATF(SKY))>150 THEN PRINT "INCORRECT INPUT!! PLEASE
REDO": GOTO 2480
2500 INPUT "SKY CONDITIONS ", SKY$(SKY)
2510 IF LEN(SKY$(SKY))>2 THEN PRINT "INCORRECT INPUT!! PLEASE
REDO": GOTO 2500
2520 SKY= SKY +1
2530 RETURN
```

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